FINAL SUMMARY REPORT ON CONTRACT Nonr 401-40

COGNITIVE SYSTEMS RESEARCH PROGRAM

by

Frank Rosenblatt
Section of Neurobiology and Behavior
Cornell University
Ithaca, New York

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Cornell University, Ithaca, New York

This program was initiated in 1959, for the purpose of studying "intelligent systems", by means of theoretical models, computer simulation, and biological experiments. While the program has been primarily supported since that time by the Office of Naval Research, some assistance has also been provided by other agencies, particularly the National Science Foundation, and (for a period of one year) the National Institutes of Health. Originally lodged with the Cornell Computing Center, the program later moved into its own premises in Hollister Hall, and since 1965 has been incorporated in the Section of Neurobiology and Behavior of the Division of Biological Sciences. Subsequent to this, the program was moved to Langmuir Laboratory, where it is now housed with the rest of this Section.

The main contributions of the CSRP have been in the fields of Applied Mathematics, Engineering, and Biological Sciences. A total of 12 Doctoral theses and 2 Masters theses have been completed, and three additional doctoral candidates are still at work under CSRP auspices. The principal activities of the program have included the following:

(1) Studies of Mathematical Models: A number of theorems in the theory of perceptrons, concerned particularly with convergence of various training procedures and comparisons of different network structures have been proven, and published in doctoral dissertations, program reports, and journal articles.

The most important contribution, in the theoretical program, is probably the development of the theory of C-system memory networks, which has demonstrated that statistically organized neural nets can achieve a memory capacity for sequences of patterns comparable to that of the human brain. In addition to the original theoretical papers by Rosenblatt, doctoral dissertations by Sloane and Petty have concerned themselves with extensions and refinements of this theory.

(2) Computer Simulation Studies: A wide variety of perceptron models, including simple perceptrons, cross-coupled and multi-layer perceptrons, and C-system models have been simulated, both at the Cornell Computing Center and at the AEC/NYU Computing Center at the Courant Institute in New York. The most extensive of these programs was Trevor Barker's general-purpose perceptron simulation program, which was used to compare performances of a large number of network types. Some of the studies included comparisons of alphabetic character recognition by perceptrons and pre-literate children; studies of pattern recognition by a perceptron employing a model of the cat's visual cortex as an input system; simulations of speech recognition systems; and adaptive networks for figure-ground segregation. A number of programs concerned with simulating the evolution of a neural network satisfying various logical and structural criteria were also run, and are being continued at this time by Dietmar Walter. A variety of conventional digital computation programs have also been completed, to aid in theoretical analyses and provide numerical examples where required. Extensive use has also been made of digital computation for statistical data processing in connection with the biological and behavioral experiments described below.

(3) Hardware Development and Testing: One of the main achievements of the CSRP has been the construction of the Tobermory Perceptron, a large-scale audio-perceptron designed for experiments in speech recognition. This work included, initially, the development of several alternative designs for analog "weights", for the memory components. George Nagy demonstrated the feasibility of a magnetoconstrictive delay component, and completed a doctoral dissertation on his work on analog weights. The final memory system made use of tape-wound magnetic core integrators, which were developed jointly with the Stanford Research Institute. The Tobermory system has been used to compare several types of sensory processing logic, and in its final form was successfully demonstrated (by Mark Scattergood) to be capable of discriminating arbitrary pairs of syllables, spoken by a variety of speakers, with reasonably good generalization to speakers it had not heard before. A supplementary program on speech synthesis was conducted by Charles Tappert, using a Melpar speech synthesizer. Tappert's doctoral thesis considers possible means of using adaptive systems for speech imitation and synthesis.

(4) Physiological and Behavioral Studies: This portion of the program (supported in part by NSF and NIH) has included electrophysiological and surgical studies of memory in cats; biochemical studies of natural products affecting learned behavior; and the development of techniques for assay of suspected transmitter substances by means of binding characteristics. Doctoral students who participated in these studies included Albert Buerger, William Herblin, Roger Marchbanks, John Farrow, Susan Othmer, and Steven Rosen.

Contributions have included the demonstration by Buerger of hippocampal involvement in memory in cats, and of spinal conditioning in kittens; demonstrations of behavioral effects of brain extracts and antibodies to brain extracts from rats trained in various tasks; and studies of neural transmitters and pharmacological interactions with transmitter binding by Marchbanks, Herblin, and Farrow. Some portions of this work are still continuing at the present time.

(5) Astronomical Photometry Studies: These include the design of a technique for detecting low-level laser signals against a relatively intense background of non-coherent light, and a study of data-processing and instrumentation for substantially improving colorimetric measurements in astronomy. The second of these programs is still continuing at this time.

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13. ABSTRACT

This report summarizes work accomplished on the Cognitive Systems Research Program for the period from 1959 to 1970. This includes construction and testing of the Tobermory Perceptron, computer simulation of perceptual and memory models, and related experimental work.

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